

ELECTRONIC FUNDAMENTALS

THEORY LESSON 20

POWER SUPPLIES I

- 20-1. Power Sources
- 20-2. Battery Power
- 20-3. D-C Power Supply
- 20-4. A-C/D-C Power Supply
- 20-5. A-C Transformer Power Supply



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Theory Lesson 20

INTRODUCTION

With this lesson you complete the first half of your course – congratulations! What is more, in the nineteen lessons that you have already completed, you have learned the electrical theory that you need to understand this and other lessons yet to come. This means that you have completed your study of the basic elements – resistance, inductance, capacitance, and electron tubes – and with this lesson will start learning how these elements are used in radio and television receivers. In this lesson, for example, you will learn how the power to operate a radio or television receiver is obtained, how to figure the amount of power needed, and how to select the proper parts to provide the power.

20-1. POWER SOURCES

One thing that you will soon discover is that radio and television circuits operate correctly only when supplied with voltages of the correct kind and value. Filaments and heaters require certain voltages to heat them; the plate, screen-grid, and control-grid voltages must be obtained from somewhere. Let's

see how we may obtain these *operating* voltages.

Perhaps the first thought that comes to mind is that we might use batteries. (In fact, that is just how the necessary voltages were obtained in the early days of radio and how today's portable and 3-way portable receivers are powered. We might use a d-c power line as a source of power and use a voltage divider to obtain the proper voltages. (We can do this only when the d-c line voltage is at least as high as the highest voltage needed.) We might use the a-c power line, reduce or raise voltages to the correct value through a transformer, and rectify the a.c. to provide d.c. Or, we might use other special devices and circuits to change d.c. to a.c. or a.c. to d.c., as needed.

In this lesson we will discuss battery d-c, a-c, and a-c/d-c power supplies; in the next lesson we will take up special power supplies and power-supply circuits.

20-2. BATTERY POWER

There is one great advantage in using batteries as a source of power; a battery pro-

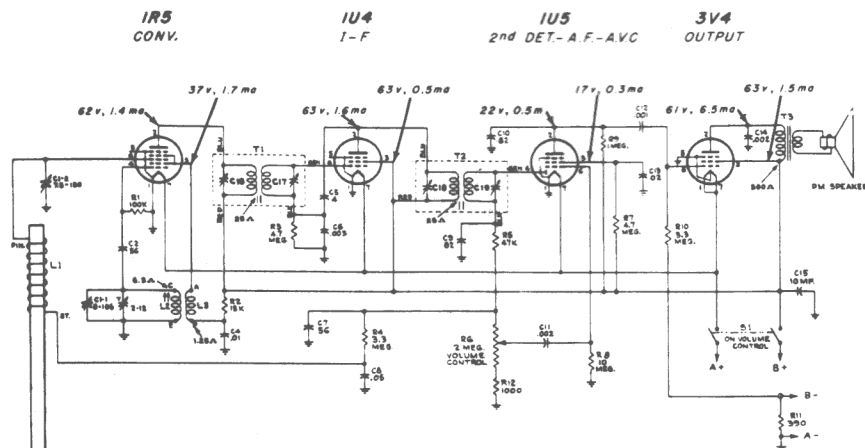


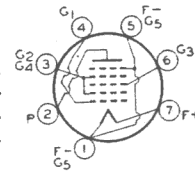
Fig. 20-1

1R5

PENTAGRID CONVERTER

Miniature type used in lightweight, portable, compact, battery-operated receivers. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in

any position. For general discussion of pentagrid types, see Frequency Conversion in ELECTRON TUBE APPLICATIONS SECTION. For filament considerations, refer to type 1U4.



FILAMENT VOLTAGE (DC).....	1.4	volts
FILAMENT CURRENT.....	0.05	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.3 to All Other Electrodes (RF Input).....	7.0	μf
Plate to All Other Electrodes (Mixer Output).....	7.5	μf
Grid No.1 to All Other Electrodes (Osc. Input).....	3.8	μf
Grid No.3 to Plate.....	0.4 max	μf
Grid No.3 to Grid No.1.....	0.2 max	μf
Grid No.1 to Plate.....	0.1 max	μf

Fig. 20-2

vides smooth, even voltage without hum. When you study audio systems, you will find that this is a very desirable characteristic. However, the output of a battery is limited and often expensive. A discharged battery needs recharging (if it is wet) or needs replacement (if dry). In addition, small, lightweight batteries normally do not last long, while large, heavy-duty batteries are generally heavy and take up a great deal of space.

However, batteries are necessary for powering portable and 3-way portable receivers. Instructions for the replacement of batteries and the servicing of such receivers was given to you in Service Practices 12; therefore, that information will not be repeated here. But you probably want to know how and why a particular battery or battery pack is selected for a particular receiver.

Let's suppose that we want to supply power to the receiver in Fig. 20-1. Upon examining the schematic drawing, we find that we must supply power to four tubes; 1R5, 1U4, 1U5, and 3V4. First, we'll find out how

much filament or *A* voltage we need. (In radio, the heater or filament voltage is usually called *A* power, the voltage supply for the screen grids and plates is called *B* power, and bias supply voltage for control grids is called *C* power).

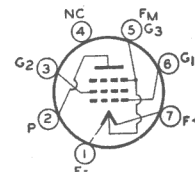
First we look up the 1R5 in the RCA Tube Manual and find (Fig. 20-2) that the tube requires 1.4 volts at 0.05 amp. Going further, we find that the 1U4 and 1U5 have the same power needs. However, when we turn to the 3V4 (Fig. 20-3), we find that the tube may operate on either 2.8 volts at 0.05 amp or 1.4 volts at 0.1 amp. If the two halves of the filament are connected in series, the tube operates on the higher voltage; if the filaments are connected in parallel, it operates on the lower voltage. Looking back at the schematic drawing, we find that the filament halves of the 3V4 are connected in parallel; so we are operating the tube at 1.4 volts and it is drawing 0.1 amp. Therefore, we need an *A* supply of 1.4 volts and 0.25 amp. For this, we can use a 1.5-volt dry cell or a battery made up of two or more 1.5-volt cells connected in parallel. It is important that the

3V4

POWER PENTODE

Miniature type used in output stage of lightweight, compact, portable, battery-operated equipment. Except for terminal connections, types 3V4 and 3Q4 are identical. Both feature

filament mid-tap so that tubes may be used either with a 1.4-volt battery supply or in series with other miniature tubes having 0.050-ampere filaments.



Filament Arrangement	Series	Parallel	
FILAMENT VOLTAGE (DC).....	2.8	1.4	volts
FILAMENT CURRENT.....	0.05	0.1	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx.):			
Grid No. 1 to Plate.....	0.2		μf
Grid No.1 to Filament, Grid No.2, and Grid No.3	5.5		μf
Plate to Filament, Grid No.2, and Grid No.3			μf

Fig. 20-3

cell or battery that we select be capable of delivering 1.4 volts at 0.25 amp for a reasonable length of time. How much time is a reasonable amount depends on several factors. If there is very little space for an *A* battery, a single cell may be used and replaced several times before it is necessary to replace the *B* battery. If the *A* supply is part of an *AB* battery pack, it is necessary that the *A* and *B* sections wear out together, because the entire pack must be replaced at one time, even if one section is still usable. In this case, a reasonable amount of time would be equal to the life of the *B* battery. How much capacity is built into a single cell depends on the purpose for which it was made. This information is not normally available to us. However, from experience we may know that a receiver with a filament drain similar to the one we have been discussing may be operated on one or two *D* cells (RCA type VS036). But if we want to be sure that we select the proper cell or battery for a particular load, we must do what receiver manufacturers do — ask the battery manufacturer which cell or battery he recommends. He can supply this information when he knows what your needs are.

Look at the schematic drawing again. The operating voltages and currents for each tube are marked for each screen grid and plate. We'll list them below:

TABLE A

Tube	Screen Grid		Plate	
	E_{G2} (v)	I_{G2} (ma)	E_b (v)	I_B (ma)
1R5	37	1.7	62	1.4
1U4	63	0.5	63	1.6
1U5	17	0.3	22	0.5
3V4	63	1.5	61	6.5

From this list, we can see that the highest voltage that we need for our *B* supply is about 63 volts. The commercial battery that delivers this much voltage is rated at 67.5 volts. However, under load, this battery delivers 63 to 65 volts, which is what we need.

Next we add all screen and plate currents and find a total of 14 ma. (Note that all currents are added, even those at voltages less than 63 volts. The lower operating voltages are obtained through dropping resistors.)

So, now we see that we need a battery that will supply 67.5 volts at 14 ma. From our experience with other receivers, we may know that a 67.5-volt battery such as the RCA type VS016 will supply our need. Otherwise, we must ask the battery manufacturer for his recommendation.

We have not discussed control-grid bias voltages. In some battery-operated sets, these may be obtained from separate *C* batteries. Later in this lesson we will discuss another way of obtaining grid bias. In another lesson, other bias methods will be discussed completely.

20-3. D-C POWER SUPPLY

Provided that the highest voltage needed does not exceed the line voltage, we may obtain power from a d-c power line. Let's assume that we must supply operating voltages for a 4-tube receiver that uses the following tubes:

1 12SA7-GT
1 12SK7
1 12SQ7
1 50L6-GT

These tubes are designed to operate with filaments connected in series. If you look them up in the tube manual, you'll find that each tube draws 0.15 ampere of heater current. The 50L6-GT requires 50 volts and the other tubes each require 12.6 volts. Connected in series, as in Fig. 20-4a, the four tubes have a total voltage drop of 87.8 volts. If the d-c line voltage is 117 volts, we must use a series resistor to drop the voltage to the needed amount (Fig. 20-4b). To find the value of resistance needed, we must first know how much voltage must be dropped across *R*. We find this by subtracting the needed voltage from the line voltage: $117 - 87.8 = 29.2$ volts. We know that the current flowing in the heater circuit is 0.15 ampere. With the information that we have,

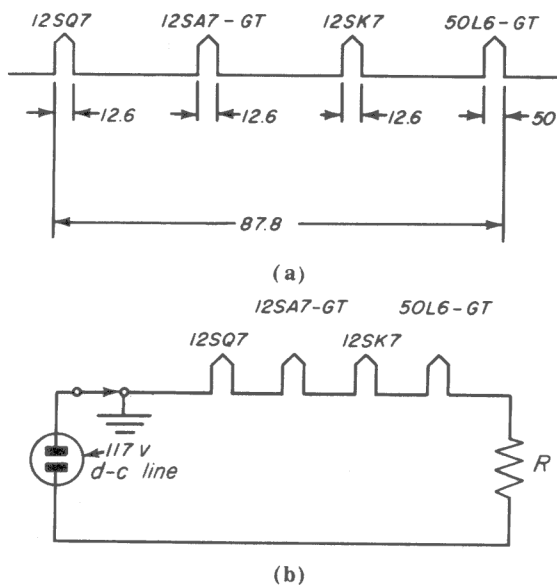


Fig. 20-4

we can use Ohm's law to find the resistor value:

$$R = \frac{29.2}{0.15}$$

$$= 195 \text{ ohms}$$

The nearest commercial resistor value is 200 ohms, which is close enough for our needs. Then we find the power rating of the resistor. We must first know how much power is consumed by the resistor:

$$P = I^2 R$$

$$= 0.15^2 \times 200$$

$$= 0.0225 \times 200$$

$$= 4.50 \text{ watts}$$

To provide the safety factor that you learned about in Theory Lesson 9, we double

the wattage, making it 9 watts. The resistor with the wattage rating nearest to our calculated value is the 10-watt resistor. So, we may use a 200-ohm, 10-watt resistor to drop the line voltage to the amount needed for our heaters.

B Supply. Next, we must figure our *B* power needs. Values of screen and plate voltages and currents were supplied to us in the schematic drawing when we calculated the *B* power needed in our battery supply. Now, we must refer to the RCA Tube Manual for operating voltages and currents. Let's start by turning to the 12SA7-GT in the tube manual. There we find that the heater voltage and current are given but, for operating voltages, we are referred to the 6SA7-GT. So, turning to the 6SA7-GT, we find much more information. At this time, we are concerned mostly with the information reproduced in Fig. 20-5. Here we find typical operating conditions. We select those listed under *Self-Excitation*. (This means that the oscillator uses grid-leak bias to be self-starting. Just what we mean by these terms is discussed later in this course. For our study of power supplies, all we need know are the conditions under which the tube operates.) We select the column headed by 100 plate volts instead of 250 plate volts, because our power line is limited to 117 volts. So, our plate voltage is 100 and the current is 3.3 ma. The screen voltage is the same with a current of 8.5 ma.

We turn next to the 12SK7 and find that we are referred to the 6SK7. Looking up the 6SK7, we find that the plate requires 100 volts at 13 ma; the screen grid requires 4 ma; and the control grid (G_1) voltage is -1 volt. Turning to the 12SQ7, we find that the operating conditions (other than heater voltage and current) are the same as for the 6SQ7. Looking up the 6SQ7, we find 100 volts

Typical Operation:

	Self-Excitation†		Separate Excitation		
Plate Voltage.....	100	250	100	250	volts
Grids-No.2-and-No.4 Voltage.....	100	100	100	100	volts
Grid-No.3 (Control-Grid) Voltage.....	0	0	-2	-2	volts
Grid-No.1 Resistor.....	20000	20000	20000	20000	ohms
Plate Resistance (Approx.).....	0.5	1.0	0.5	1.0	megohm
Conversion Transconductance.....	425	450	425	450	μmhos
Grid-No.3 Voltage (Approx.) for transconductance of 10 μmhos.....	-25	-25	-25	-25	volts
Grid-No.3 Voltage (Approx.) for conversion transconductance of 100 μmhos....	-9	-9	-9	-9	volts
Plate Current.....	3.3	3.5	3.3	3.5	ma
Grids-No.2-and-No.4 Current.....	8.5	8.5	8.5	8.5	ma
Grid-No.1 Current.....	0.5	0.5	0.5	0.5	ma
Total Cathode Current.....	12.3	12.5	12.3	12.5	ma

Fig. 20-5

Typical Operation:

	Fixed Bias	Cathode Bias	
Plate Voltage.....	110	200	volts
Grid-No.2 Voltage.....	110	125	volts
Grid-No.1 (Control-Grid) Voltage.....	-7.5	-	volts
Peak AF Grid-No.1 Voltage.....	7.5	8.0	volts
Cathode Resistor.....	-	180	ohm
Zero-Signal Plate Current.....	49	46	ma
Maximum-Signal Plate Current.....	50	47	ma
Zero-Signal Grid-No.2 Current (Approx.).....	4	2.2	ma
Maximum-Signal Grid-No.2 Current (Approx.).....	10	8.5	ma
Plate Resistance (Approx.).....	13000	28000	ohms
Transconductance.....	8000	8000	μmhos
Load Resistance.....	2000	4000	ohms
Total Harmonic Distortion.....	10	10	per cent
Maximum-Signal Power Output.....	2.1	3.8	watts

Fig. 20-6

at 0.5 ampere for the plate. This tube has no screen grid, so there is no listing for screen voltage and current. The grid voltage is -1. However, this voltage is not obtained from our power supply, so we need not worry about it now. Finally, we look up the 50L6-GT and find the full information that is reproduced in Fig. 20-6. We find that the plate and screen voltages are each 110 volts, with the plate drawing 49 ma and the screen 4 ma. Let's list all of these values so that we can see at a glance what our needs are:

TABLE B

Tube	Control Grid	Screen Grid		Plate	
	E_c (v)	E_{G2} (v)	I_{G2} (ma)	E_b (v)	I_b (ma)
12SA7-GT	0	100	8.5	100	3.3
12SK7	-1	100	4.0	100	13.0
12SQ7	-	-	-	100	0.5
50L6-GT	-7.5	110	4.0	110	49

From the table we can see that we need 29.3 ma at 100 volts and 53 ma at 110 volts. In addition, we need two bias voltages, -1 and -7.5 volts. To obtain these voltages, we need a voltage divider similar to that shown in Fig. 20-7. The sum of +110 volts and -7.5 volts is exactly 117.5 volts. If the d-c line delivers exactly 117 volts, we are shy one-half a volt. If we took half a volt from the -7.5 volts bias and made it 7 volts instead, the small difference might have a greater effect on the operating conditions of the tube than if we were to take one half volt from the plate and screen voltage. The tube will operate just as well on

109.5 volts as it will on 110 volts. So, in the drawing of the voltage divider we have made, the voltage swings from +109.5 volts to -7.5 volts, for a total of 117 volts.

The values of the resistor that make up the voltage divider may be found by using Ohm's law. The total current needed for the tubes is the sum of 53 ma and 29.3 ma, or 82.3 ma. To this, we add 10-percent bleeder current (8.2 ma). This gives us a total of 90.5 ma. Therefore, the current flowing through R_1 is 90.5 ma less 53 ma, or 37.5 ma. The voltage drop across it is 9.5 volts. With this information, we can find R_1 :

$$R_1 = \frac{9.5}{0.0375} = 253 \text{ ohms.}$$

The nearest commercial resistor value is 240 ohms, which we may use.

The only current flowing through R_2 is the bleeder current (8.2 ma). The voltage across the resistor is 100 volts. We find R_2 .

$$R_2 = \frac{100}{0.0082} = 12,195 \text{ ohms}$$

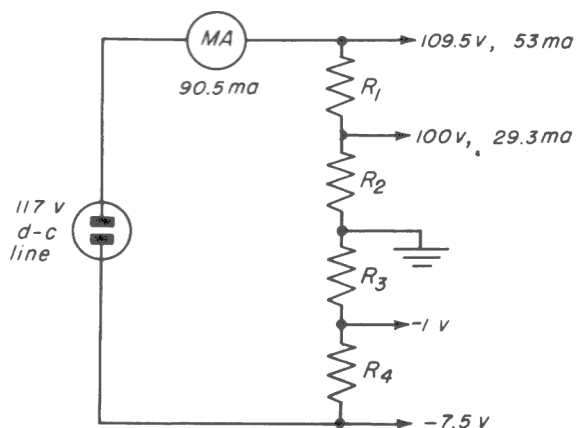


Fig. 20-7

The nearest commercial value is 12,000 ohms, which is close enough for our purposes.

All of the current flows through resistors R_3 and R_4 . We find R_3 :

$$R_3 = \frac{1}{0.0905} = 11 \text{ ohms}$$

And, finally, we find R_4 :

$$R_4 = \frac{6.5}{0.0905} = 72 \text{ ohms.}$$

The 11-ohm resistor, R_3 , may be readily obtained; however, the nearest value to 72 ohms (for R_3) is 75 ohms in a commercially made resistor. If the 72-ohm value is necessary, a 75-ohm or 100-ohm adjustable wire-wound resistor may be adjusted to exactly 72 ohms; otherwise, we use a 75-ohm resistor.

D-C power lines require filtering because of generator ripple caused by slight differences in voltage between commutator segments, the slots between the segments (when current is interrupted), and brush sparking

(caused by dirty and uneven contacts). The cut-off frequency of a filter designed for filtering d-c ripple may be found by using this formula:

$$F_c = \frac{\text{number of segments} \times \text{rpm}}{60}$$

L, T, and π -type filters, such as those used in a-c power supplies, are usually effective in reducing the ripple satisfactorily. For example, the filter used in an a-c/d-c power supply filters either the a-c ripple from rectified a.c. or the d-c ripple from a d-c power line.

Look at Fig. 20-7 again. Notice that the line-cord plug must be connected with the right polarity, or else the tube plates will receive voltages that are negative with respect to their cathode. Under these conditions, the tubes cannot operate.

20.4. A-C/D-C POWER SUPPLY

Let's assume that we must supply power to a 6-tube receiver that is to operate on 117 volts a.c. or d.c. The tubes are:

No. Used	Designation
1	12SA7-GT
2	12SK7
1	12SQ7
1	35L6-GT
1	35Z5-GT

The filaments are connected in series, as shown in Fig. 20-8a. The total voltage drop

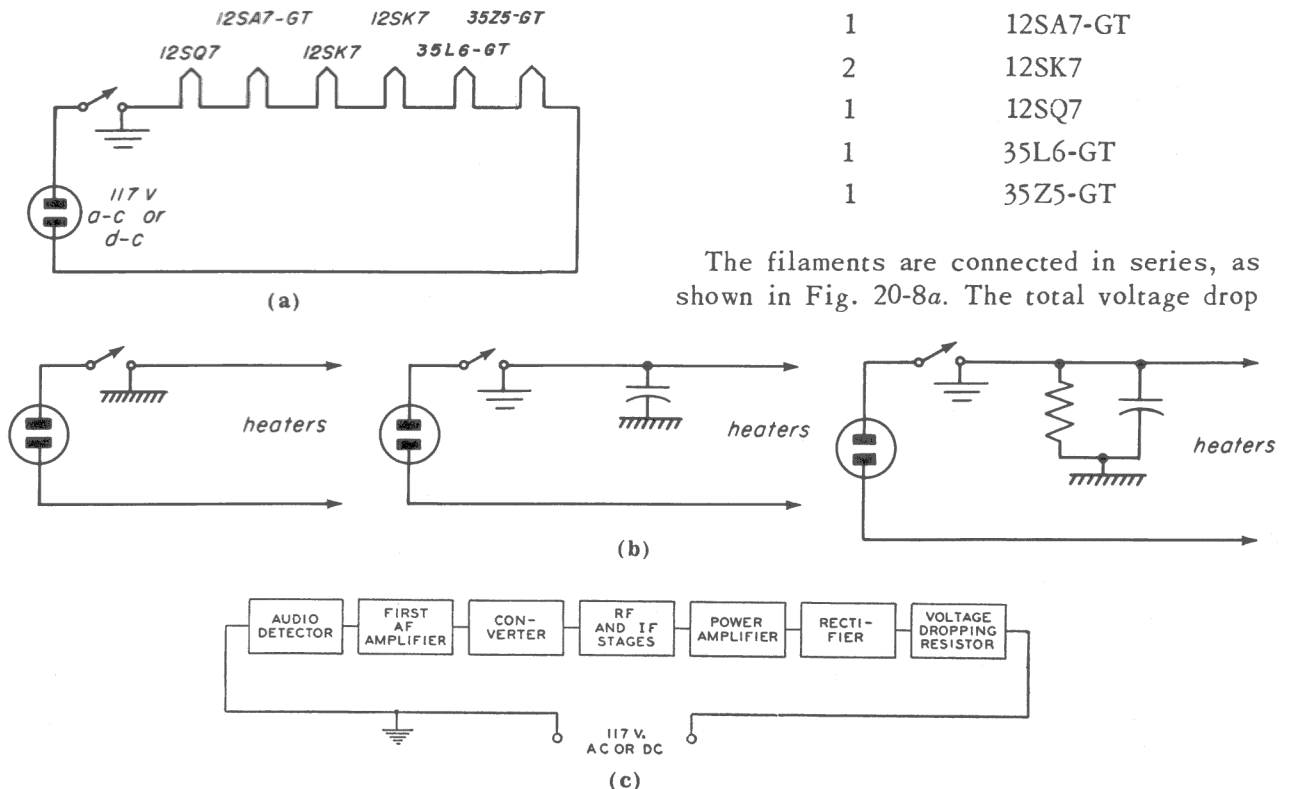


Fig. 20-8

of the six tubes in series equals 120 volts, so no series dropping resistor is necessary.

Notice, in Figs. 20-4*b* and 20-8*a*, that one end of the heater circuit is grounded. In some receivers this means a direct connection to the chassis. In others, it means a connection to a common ground wire that is insulated from the chassis or that is electrically connected to the chassis through a capacitor (usually 0.1 to 0.25 μ f) or through an RC filter (usually 250 k-ohms and 0.25 μ f). See Fig. 20-8*b*.

Furthermore, be sure to notice that the tube heaters are connected together in a definite order, with the 12SQ7 being nearest to ground. This is done to prevent the pickup and amplification of a-c or d-c ripple, and so prevent hum from reaching the loudspeaker.

Figure 20-8*c* shows the normal order of connection of heaters in a series heater string. Because the 12SQ7 is a combination detector and audio tube that can pickup and amplify ripple frequencies, it is placed nearest to ground.

B Power Supply. Next, we must find out how much *B* voltage and current is needed to power the receiver. We already know the voltage and current needs of the 12SQ7,

12SA7-GT, and 12SK7, so we do not have to look them up again but can copy them over from the table we used in the last section.

It will be necessary to look up the 35L6-GT in the tube manual. The 35Z5-GT is the rectifier tube that supplies the *B* power for the other tubes. For that reason, it does not appear in the Table C.

In figuring the power requirements, we can ignore the grid bias because the bias voltages are obtained by a method that is discussed fully in a later lesson. Therefore, we will concern ourselves with only the *B*-power needs.

Let us consider why we chose the 35Z5-GT. Checking over the table below, we find that 46.3 ma is needed at 100 volts and 43 ma at 110 volts — making a total of 89.3 ma. While we have chosen a rectifier — the 35Z5-GT — already, let's look in the tube manual to see what choice we have. Turn to the Receiving Tube Classification Chart (you'll find the page number in the Table of Contents on the inside front cover). There, you'll find a table showing different types of rectifiers (Fig. 20-9).

To use this table, we must know what we are looking for. First of all, we are looking for half-wave rectifiers; except under very unusual conditions, this is the only type of

TABLE C

Service	Tube	Control Grid	Screen Grid		Plate	
		E_c (v)	E_{G2} (v)	I_{G2} (ma)	E_b (v)	I_b (ma)
R-F amplifier	12SK7	-1	100	4.0	100	13.0
Converter	12SA7-GT	0	100	8.5	100	3.3
I-F amplifier	12SK7	-1	100	4.0	100	13.0
Det-1st AF	12SQ7				100	0.5
Power amplifier	35L6-GT	-7.5	110	3.0	110	40.0

Filament or Heater Volts			1.25—1.4			2.0—5.0			6.3—117.0		
			Sub-miniature	Miniature	Other	Octal	Other	Miniature	Octal	Other	
RECTIFIERS (For rectifiers with amplifier units, see POWER AMPLIFIERS).											
Half-Wave	vacuum	Peak Inverse Volts: Below 1500						35W4 117Z3	6AX4-GT 12AX4-CT 35Z4-CT 35Z5-CT	6W4-GT 25W4-CT 35Z3-CT	1-v 35Y4 35Z3
		Above 1500		1V2 (1X2-A) (1X2-B)	1B3-GT	3A3	3/2		6AU4-GT		
Full-Wave	vacuum	Peak Inverse Volts: Below 1500				(5Y3-C, 5Z4 5Y3-GT, 5Y4-G 5V4-G, 5W4-CT 83-v)	5A24 80	(6X4 12X4)	6X5, 6X5-GT 6AX5-GT		7Y4 7Z4 6Z4
		Above 1500				(5T4, 5U4-G 5X4-G)	5Z3				
	mercury-vapor	Above 1500					83				
	gas	Below 1500				Cold-Cathode Types 0Z4, 0Z4-G					
Doubler	vacuum	Peak Inverse Volts: Below 1500							(25Z6, 25Z6-GT 50Y6-CT 50Y7-GT 117Z6-GT	25Z5	50X6

Fig. 20-9

rectifier that works directly from a power line without a transformer or without sacrificing voltage. Next, we are looking for a rectifier that has a 35-volt heater, so that we may avoid using a series dropping resistor in the heater string. We find these listed in the portion of the chart that is circled. We find five 35-volt rectifiers listed: 35W4, 35Z4-GT, 35Z5-GT, 35Y4, and 35Z3. On looking them up, individually in the tube manual, we find that only the 35W4 and 35Z5-GT are being used in new equipment. The other tubes are marked "for renewal purposes," which means that those made today are for replacement in old receivers and other equipment, and that tube factories may stopmaking them.

The rectifier that we are looking for should draw 0.15 ampere, which both the 35W4 and the 35Z5-GT do. In addition, the rectifier we want should be able to deliver about 100 ma (89.3 ma is the actual figure). Under the heading *Typical Operation Without Panel Lamp*, we find that either of the tubes will supply our needs. The main difference between the tubes seems to be that one, 35W4, is a miniature-base tube and the

other, the 35Z5-GT, is an octal-base tube. The other tubes that we are using are all octal based, so we might as well use the 35Z5-GT — which we planned to do all along.

There is one point that you will do well to remember and that is: try to avoid operating tubes at maximum rated currents and voltages. You add to the life of the tube by operating it at about 90 percent of its maximum ratings. By operating a tube at maximum or more than maximum, its life is shortened. Of course, if a rectifier must deliver its maximum output because the receiver cannot operate satisfactorily with its tubes working at lower current drains, nothing much can be done about it. However, it is possible that 10 ma might be saved by operating each of the tubes at slightly less voltage than we planned to. For the present, we will continue with our plans to operate the tubes at the voltages already selected.

Filtering. Now that we have checked the heater circuit and the rectifier, we must consider the filtering necessary to cut out a-c or d-c ripple. Most a-c/d-c receivers use π -

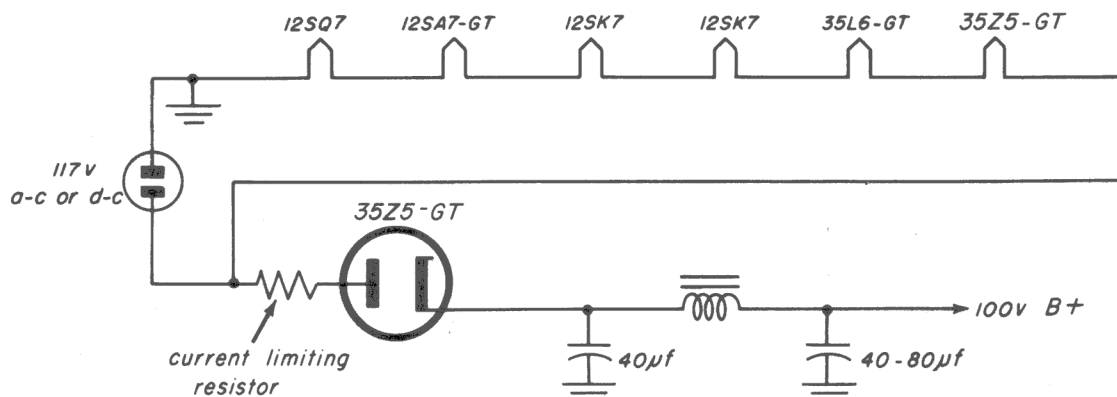


Fig. 20-10

Typical Operation without Panel Lamp:

AC Plate-Supply Voltage (rms)	117	235	volts
Filter-Input Capacitor	40	40	μ f
Minimum Total Effective Plate-Supply Impedance	15	100	ohms
DC Output Current	100	100	ma
DC Output Voltage at Input to Filter (Approx.):			
At half-load current (50 ma.)	140	280	volts
At full-load current (100 ma.)	120	235	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	20	45	volts

Fig. 20-11

type, low-pass RC, or LC filtering. If LC filtering is used, as in Fig. 20-10, a choke must be selected that can safely pass 100 ma. In a replacement parts catalog, we can find listings of filter chokes. Among them, there'll be one that suits our needs. For example, a choke rated at 10.5 henries, 110 ma, and 220 ohms resistance is typical of the type of choke we are looking for.

The fact that the choke has a resistance of 220 ohms presents us with another problem. With 100 ma flowing through 220 ohms, the voltage drop is 22 volts. Look at the 35Z5-GT data reproduced in Fig. 20-11. Note that the rectified d-c voltage to the filter input is 120 volts at full-load current (100 ma). If we subtract 22 volts from this figure, the filtered d.c. at the output of the filter is about 98 volts. If the 35L6-GT operates at this lower voltage, it will draw less current than at 110 volts, so the voltage drop across the choke will be slightly less, with the result that the 35L6-GT will operate at about 100 volts. This is close enough to the original operating point for our purposes.

Look again at Fig. 20-11. Note that the filter-input capacitor is rated at 40 μ f. If this value is exceeded, the cathode-to-plate current while the capacitor charges may be more than the tube can handle. As a safety measure, the connection between the cathode pin and the cathode is made so that it will fuse (melt) if the current becomes excessive. When this happens, the connection between the cathode pin and the cathode (called the cathode tab) opens up and the tube no longer rectifies even though the tube heater lights up.

Larger values of input capacitance may be used if a current-limiting resistor is placed in series with the rectifier plate (Fig. 20-10). A safe value of resistance for a 100-ma load is 25 to 50 ohms. The slight voltage drop that appears across the resis-

tor after the capacitors are charged does not have any noticeable effect on the operation of the receiver. However, during the charging period, when the surge current may be as high as 600 to 700 ma, the voltage drop across the resistor is enough to drop the operating voltage on the plate and so reduce the current to a safe point.

Current-limiting resistors are sometimes used even when the surge current during the charging cycle is not normally high. In these cases, it is used as a safety measure to prevent "blowing" the rectifier when the receiver is turned on at a time when the rectifier heater is already hot. This condition occurs when a receiver is tuned off and then on again within a few moments, as, for example, when someone plays with the power switch — turning it off and on without purpose. Let's see what happens in the power-supply circuit when this occurs. First let's consider what happens as the receiver is turned on when all the tubes are cold. It takes from 30 to 45 seconds for the heaters to bring the cathodes up to normal operating emission. As the rectifier heats, it gradually supplies current to the filter capacitor and to the tubes, and the surge current is within safe limits. However, when the receiver tubes are heated, the story is different. When the receiver is turned off, the filter capacitors discharge almost immediately. Then when the switch is turned on again, the capacitors demand a surge of current to recharge them. In the meantime, the heated tubes also demand normal operating current immediately and cause the surge current to increase — sometimes beyond the peak current capacity of the tube. In such cases, the cathode tab opens and the tube is blown. For this reason, a current-limiting resistor is always advisable.

So, our input filter capacitor has a capacity of 40 μ f, while the output capacitor is usually some value between 40 and 80 μ f. In the lesson on basic filters, you learned that low-

pass filters may be designed to cut off at a particular frequency, and that certain values of L and C are used for such filters. In practical receiver filters, chokes with high inductance values are not often used. This is simply because they are expensive. Instead, *brute-force* filtering is more often used. Brute-force filtering is defined as the kind of filtering that uses a combination of large capacities and small inductance without much thought of an exact cut-off frequency. The reason this is done is that high-capacity electrolytic capacitors are inexpensive and, when combined with a low-inductance choke, work quite as well as a filter made from smaller capacitances and higher inductance.

RC Filter. If a resistor is used instead of the choke, it normally has a value of between 1,000 and 2,000 ohms. While a resistor is much cheaper than a choke, sometimes it is not practical to use a resistor instead of a choke because the voltage output of the filter may be much less than we need. For example, in the receiver that we have just been discussing, the 100 ma drawn by the tubes would produce a voltage drop of 100 volts across a 1,000-ohm resistor. Of course, this produces an impossible condition because the output of the filter would be so small that the tubes would be operating at voltages too low for them to be drawing 100 ma. In actual practice, the output of the filter might be between 80 and 90 volts and the current drain considerably less than 100 ma. The point to remember is that an RC filter normally produces a lower output voltage than an equal LC filter.

The Rectifier Heater Tap. The typical operating conditions for the 35Z5-GT, as shown in Fig. 20-11, were for operation without a panel lamp (pilot light). Both the 35W4 and 35Z5-GT rectifiers have tapped heaters for panel-lamp connection. The tube-manual schematic symbol for the 35Z5-GT (Fig. 20-12a) shows heater connections at pins 2, 3, and 7. The entire heater is connected between pins 2 and 7, with a tap at pin 3. As shown in the simplified drawing (Fig. 20-12b), the heater resistance that makes up the heater is divided so that the voltage between pins 2 and 3 is 7.5 volts and between pins 3 and 7 is 27.5 volts — making a total of 35 volts. A 150-ma 6 to 8

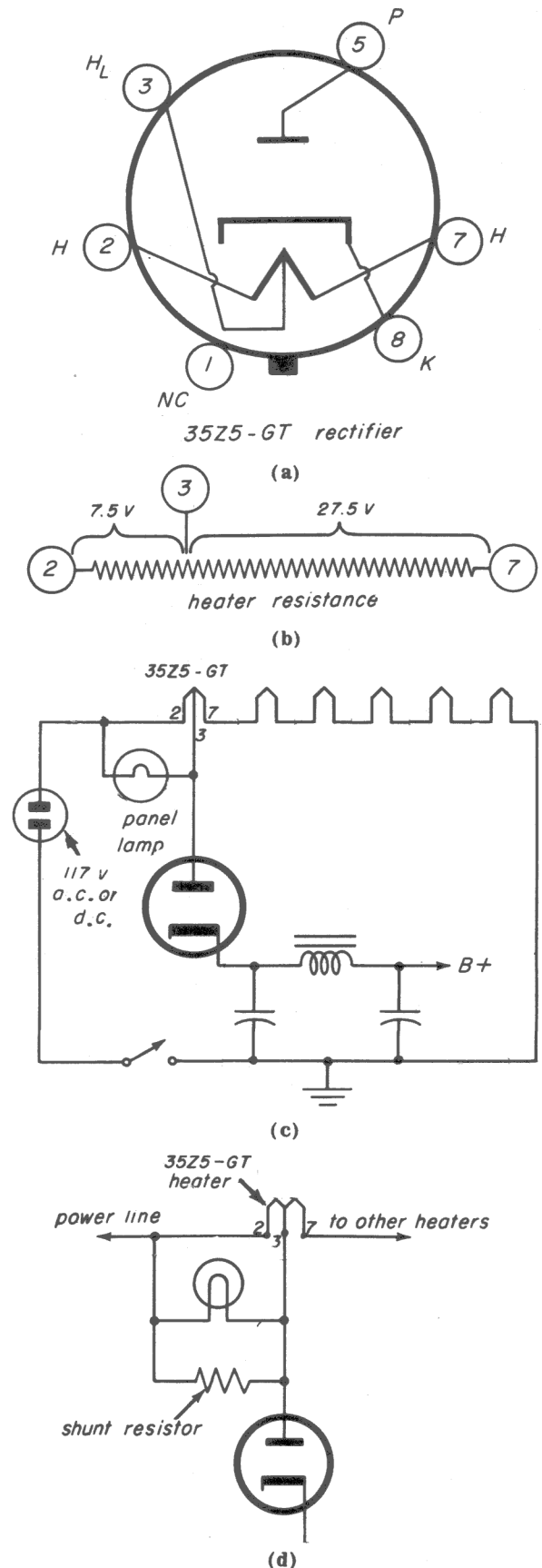


Fig. 20-12

volt panel lamp, such as the #40 or #47, may be connected to pins 2 and 3, which places it in shunt with the 7.5-volt heater section (Fig. 20-12c). In some receivers, the rectifier plate is connected to the heater tap instead of directly to the power line (Fig. 20-12d). When so connected, the plate current passes through the parallel circuit of the heater section and panel lamp filament. In these receivers, the panel-lamp flickers as the signal becomes louder or softer because the plate current, flowing through the lamp, rises and falls with the signal voltage.

However, when the panel lamp burns out, the section of the heater between pins 2 and 3 becomes overloaded. The rectifier heater is designed to carry no more than 150 ma, which is the normal heater current of the heater string. The shunted panel lamp can carry up to 150 ma, which added to the 150 ma of the heater section makes a total of 300 ma. Normally, the heater current and plate current combined do not exceed 250 ma (when the maximum plate current is being drawn), so the parallel heater and panel-lamp circuit easily handles the load. But when the panel lamp burns out, all of the heater current and all of the plate current flow through the panel-lamp section of the heater, which may cause that portion of the heater to burn out. To prevent such burnout, some manufacturers and servicemen place a resistor in shunt with pins 2 and 3 of the rectifier heater. The value of resistance needed is determined by the plate current flowing through the tube. Under the heading *Maximum Circuit Values*, the RCA Tube Manual says that a shunt resistor is needed when the plate current of the 35Z5-GT exceeds 60 ma. The Manual recommends an 800-ohm resistor when the d-c current is 70 ma, a 400-ohm resistor when the current is 80 ma, and a 250-ohm resistor when the current is 90 ma. When the plate current is 100 ma, no panel lamp should be connected in shunt with the heater and the rectifier plate should not be connected to the heater tap. Other authorities recommend that an 800-ohm resistor be placed in shunt with heater pins 2 and 3 even if no panel lamp is connected.

Selenium Rectifier. Many modern a-c/d-c receivers use selenium rectifiers instead of an electron-tube rectifier. The selenium

rectifier has several advantages over the tube. Among these are small size, cool operation, no warm-up time, low voltage drop, and two-terminal ease of connection. If one were used in place of the 35Z5-GT in the receiver that we have just been discussing, a series-dropping resistor would have to be used instead of the 35-volt heater of the tube. The current flowing through the resistor would be 0.15 ampere, so the resistor would be:

$$R = \frac{35}{0.15}$$

$$= 233 \text{ ohms}$$

The nearest commercial value is 240 ohms, which is close enough.

Next we would select a selenium rectifier capable of handling 100 ma.

Caution: It is very important that the cathode of the rectifier be connected as shown in Fig. 20-13. If the connections are reversed, the large current that flows through the rectifier will cause it to "cook", and selenium dioxide fumes will be emitted. These fumes are poisonous and should not be breathed. If ever you find a selenium rectifier that is overheated, it is connected incorrectly or is overloaded. Try to get it out of doors as quickly as possible and get out of the room that it was in until the room has had a chance to air completely. Above all, do not touch the rectifier while it is hot. If you do, you may receive a selenium burn and be poisoned by it.

To prevent surges of current from overloading the rectifier, a current-limiting resistor is placed in series with the rectifier (Fig. 20-13). The value of this resistor varies with the load. If the current is 50 ma, the resistor should be between 50 and 75 ohms. If it is 100 ma, the resistor should be some value between 25 and 50 ohms.

Some receiver manufacturers use selenium rectifiers only when they are isolated (kept separate) from the power line by an *isolation* transformer. An isolation transformer is one that usually has a 1 to 1 turns ratio and is used to keep a radio or other electric circuit

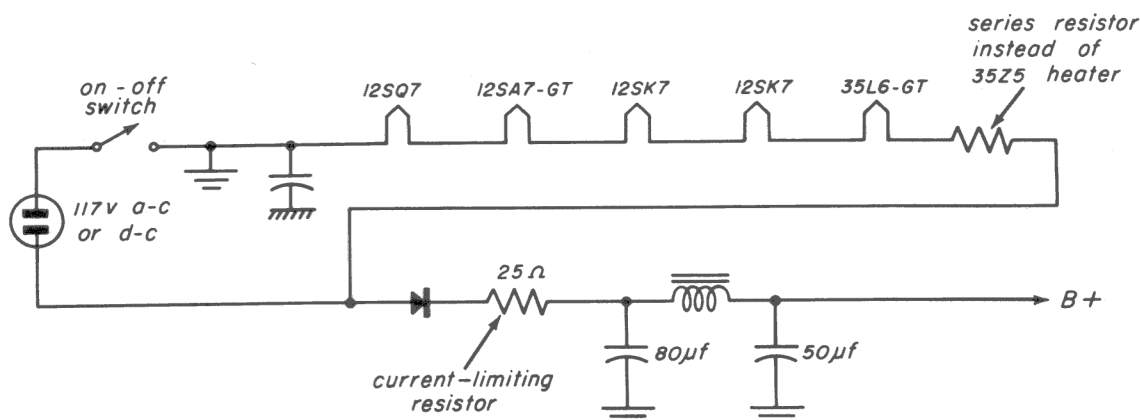


Fig. 20-13

away from direct contact with the power line. If a transformer is used, no current-limiting resistor is necessary because the transformer will limit peak values of current. If no transformer is used and the rectifier is connected directly to the power line, certain precautions must be taken:

1. Do not connect the chassis to B- (the power line). Instead, run a separate B- wire that is insulated from the chassis and that is connected to the chassis through a 0.05- or 0.1- μ f capacitor.

2. Unless the receiver is to be housed in a plastic cabinet, the tuning-capacitor shaft should be insulated from the chassis.

3. Mount the rectifier in a cool place on the top side of the chassis.

4. Never exceed the current-carrying capacity of a selenium rectifier. In fact, it is a good idea to operate such a rectifier at 90 percent of its current capacity.

5. Be sure that the selenium rectifier is connected with the correct polarity.

20-5. A-C TRANSFORMER POWER SUPPLY

Full-Wave Electron-Tube Power Supply.

As you learned in Lessons 17 and 18, transformers may supply half-wave and full-wave rectifiers. In this lesson, we have been discussing half-wave rectifier power supplies. However, most a-c transformer-operated supplies use full-wave rectification. For this reason, this part of the lesson is devoted

mostly to full-wave power supplies. Much of the information that you will receive in this part of the lesson applies equally well to half-wave power supplies. For this reason, you will want to study it carefully.

To begin, let's suppose that we want to supply power to a receiver that employs the following electron tubes:

R-F amplifier	6AU6
Converter	6BE6
I-F amplifier	6BA6
Detector A.F.	6AV6
Audio output	6V6-GT

The tubes are to be operated at potentials suggested in the tube manual, so we'll see what the manual says. We'll start with the 6AU6. Turning to the listing in the RCA Tube Manual, we find that the heater requires 0.3 amperes at 6.3 volts. Under the heading, *Typical Operation (Pentode Connection)*, we find that we may operate the tube with 250 volts on the plate and 125 volts on the screen (G_2). Under these conditions, the grid (G_1) bias is -5.5 volts, the plate current is 7.6 ma, and the screen current is 3.0 ma.

Next we look up the 6BE6, which is a multigrid tube called a pentagrid converter, and find that it too needs 0.3 amperes at 6.3 volts for the heater. We will operate the tube with 100 volts on the plate and on the screen (G_2). Under these conditions, the plate current is 2.6 ma and the screen current is 7.0 ma. The control grid (G_1) bias voltage is -1.5 volts.

Next in turn, we look up the 6BA6, then the 6AV6, and finally the 6V6-GT, and find the operating voltages and currents as listed in Table D.

TABLE D

Tube	Heater		Plate		Screen	
	E (v)	I (a)	E _b (v)	I _b (ma)	E _{G2}	I _{G2}
6AU6	6.3	0.3	250	7.6	125	3.0
6BE6	6.3	0.3	100	2.6	100	7.0
6BA6	6.3	0.3	250	11	100	4.2
6AV6	6.3	0.3	250	1.2		
6V6-GT	6.3	0.45	180	29	180	3.0

The heaters of the electron tubes used in the d-c and a-c/d-c receivers we have been discussing were connected in series. This means that when one of them burns out, the heater circuit opens up and the entire series string of heaters is without power until the burned-out tube is replaced.

The tubes that we are now planning a power supply for all require the same heater voltage so they may be supplied by a low-voltage power-transformer secondary rated at 6.3 volts and capable of supplying a total of 1.65 ampere. Most receivers use panel lamps to light up the tuning dial and tuning controls, so we will use two #44 panel lamps, which are rated at 0.25 ampere at 6.3 volts. Two of these panel lamps will add 0.5 ampere to the 1.65 amperes needed for the heaters, making a total of 2.15 ampere that the 6.3-volt secondary must supply.

We will assume that the grid-bias voltages will be obtained from some source other than

from the voltage-divider system, so we can ignore these voltages and concentrate on the heater, plate, and screen voltages and currents. For our power supply, we must choose the correct power transformer, rectifier tube, low-pass filter, and voltage-divider system. Before we can do this, we must first find out what our voltage and current needs are. Looking at the table above, we find that we need 19.8 ma at 250 volts, 32 ma at 180 volts, 3 ma at 125 volts, and 13.8 ma at 100 volts. This makes a total of 68.6 ma. The standard values of bleeder current is either 5% or 10%. We will use 10%, which adds 6.9 ma to our current needs, making a grand total of 75.5 ma. The values of each section of the voltage divider may now be found by the methods you have already learned.

Before we can select a power transformer for our power supply, we must first select a filter choke and the full-wave rectifier tube. A typical value for the filter choke is 10 henrys, so we will select a filter choke from the parts catalog that has a value of approximately 10 henrys and can safely pass 75.5 ma. It has already been suggested that we operate a filter choke at about 90% of its maximum current capacity. For this reason, we will look for a choke rated at between 80 and 85 ma. Figure 20-14 shows a typical listing of filter chokes. The arrow points to a choke that we might use. It is rated at 12 henrys with a current drain of 80 ma and has a resistance of 375 ohms. With 75.5 ma flowing through this choke, the voltage drop will be approximately 28 volts. This voltage must be added to the 250 volts that we need for the tubes so that we may know what voltage

TYPE NO	LIST PRICE	INDUCTANCE HENRYS	AT MADC	RESISTANCE OHMS	RM TEST VOLTS	MTG CENTERS	HEIGHT
20C58	\$3.00	0.75	0.5	30	1100	2 3/8	1 5/8
		0.75	10				
20C50	5.00	350	5	5500	2200	2 7/8	2
		150	15				
20C63	6.50	135	5	6500	1500	2 3/8 x 1 1/2	2 7/8
20C40	2.00	1.5	10	95	1500	1 3/4	1 1/4
20C51	2.30	35	15	1850	1200	2	1 3/8
20C52	2.50	12	20	450	1200	2	1 3/8
		8	40				
		4	65				
20C42	3.00	4.5	50	200	1500	2 3/8	1 5/8
20C66	3.00	9	50	500	2500	2 3/8	1 5/8
20C59	3.00	9	45	200	1600	2 3/8	1 5/8
		7	55				
		5	65				
20C65	3.50	6	75	200	1600	2 3/8	2 3/8
→ 20C53	3.50	17	60	375	2500	2 7/8	2
		12	80				
		8	100				
20C64	4.50	7	100	100	1600	3 1/8	2 1/4
		4	130				
		3	150				

Fig. 20-14

Typical Operation with Capacitor Input to Filter:			
(A) AC Plate-to-Plate Supply Voltage (rms).....	700	1000	volts
Filter Input Capacitor*.....	10	10	μ f
Effective Plate-Supply Impedance Per Plate.....	50	140	ohms
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of { 62.5 ma	390	—	volts
42 ma	—	610	volts
At full-load current of { 125 ma	350	—	volts
84 ma	—	560	volts
Voltage Regulation (Approx.):			
Half-load to full-load current.....	40	50	volts
Typical Operation with Choke Input to Filter:			
AC Plate-to-Plate Supply Voltage (rms).....	700	1000	volts
Filter Input Choke.....	10 #	10 #	henries
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of { 75 ma	270	—	volts
62.5 ma	—	405	volts
At full-load current of { 150 ma	245	—	volts
125 ma	—	390	volts
Voltage Regulation (Approx.):			
Half-load to full-load current.....	25	15	volts

(B) * Higher values of capacitance than indicated may be used but the effective plate supply impedance may have to be increased to prevent exceeding the maximum rating for hot-switching transient plate current.

Fig. 20-15

the transformer and rectifier must supply to the filter input. When we have selected a rectifier, we will see how important this information is.

A convenient way to find what rectifier tubes are available is to turn to the RCA Receiving Tube Classification Chart in the Tube Manual. Most power transformers designed for receivers provide either a 5-volt or 6-volt supply for the rectifier heater. Let's assume a 5-volt winding is provided. We will then look at only those rectifiers listed in the 2.0 – 5.0 volt column of the chart. Many tubes are listed in the full-wave section of the chart. However, many of them may be eliminated because they are either on the Not Recommended list on the inside back cover of the tube manual, or listed as being for renewal service only in their individual listings in the manual.

Thus, we are left with four or five tubes to choose from. Looking these remaining tubes up in the manual, we find that all but one – the 5Y3-GT – supply more current than the 75 ma that we need. Since the others cost more, as you can see by checking their price in a current catalog, there is no point in using them. Also, some of them require more filament current than the 5Y3-GT. This extra filament current would result in wasted power. For these reasons, the 5Y3-GT tube is our best choice in this case.

Looking at the 5Y3-GT listing in the tube manual, we find that the operation of the tube depends partly on the type of filter used. Typical operation conditions are given for a capacitor-input filter and for a choke-input filter. We will study each, starting with the capacitor input. Under the heading *Typical Operation with Capacitor Input to Filter*, we find that a value of 10 μ f is recommended for the input capacitor (A, Fig. 20-15). We find, too, that a higher value of capacitance may be used if the impedance of the plate supply (the transformer high-voltage secondary) is high enough to prevent current surges from exceeding the tube's peak current carrying capacity (B of same Figure). However, we'll assume that our pi-type low pass filter has 10- μ f input and output capacitors, which are normal values to go with the 12-henry choke that we have already selected.

We know that the rectifier must deliver 75.5 ma at 278 volts to the filter input. By referring to the *Operation Characteristics* graph (reproduced in Fig. 20-16), we can find out how much rms a.c. must be applied to the rectifier plates to deliver the voltage that we need. At the 75.5 ma point on the horizontal axis, we erect a vertical line, and from the 278-volt point on the vertical axis we draw a horizontal line. These two lines meet at a point about halfway between the 250- and 300-volt rms plate curves, which means that the a-c voltage applied to each plate of the rectifier should have an rms value of about 275 volts.

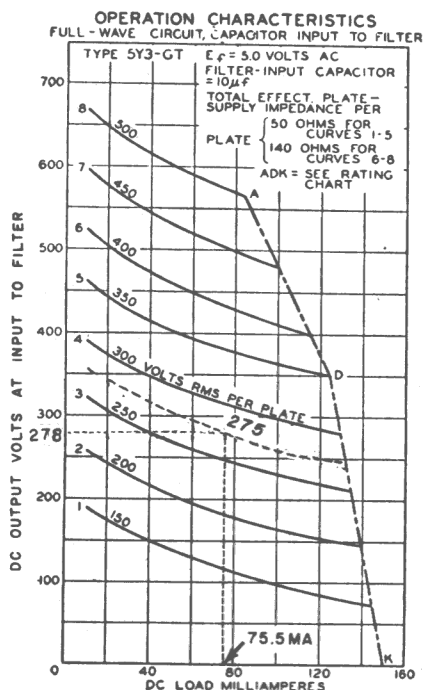


Fig. 20-16

Now we look at the *Rating Chart* graph (reproduced in Fig. 20-17) to see if the rectifier can supply the current we need with 275 volts RMS on each plate. From the 275-volt point on the horizontal axis, we erect a vertical line to the curve marked *Max. Operating Values with Capacitor Input to Filter*. From the point where the vertical line meets the curve, we draw a horizontal line to the vertical axis and find that the d-c output current to the filter input is about 65 for each plate, for a total of 130 ma. This much more than we need, so we can be sure that the

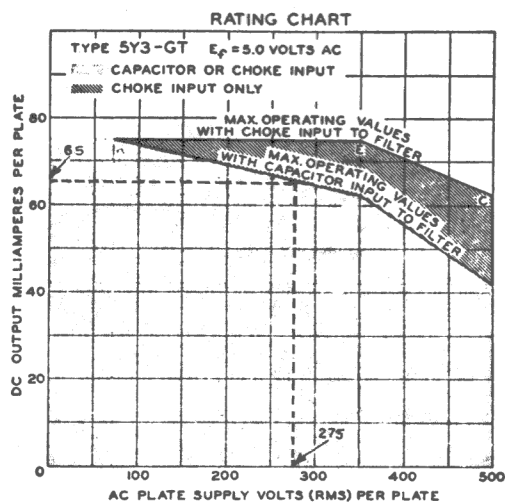


Fig. 20-17

tube can handle the current without overloading.

We now have all the information that we need to enable us to select a suitable power transformer. We are looking for a transformer that has a primary winding designed for a 117-volt, 60 cycle a.c. power line. It must have a 5-volt rectifier heater secondary with a 2-ampere capacity, a 6.3-volt secondary capable of supplying at least 2.15 amperes, and a high-voltage secondary rated at 275 volts each side of the center tap that will deliver about 80 ma. Looking at our catalog, we find one (marked with an arrow in Fig. 20-18) that supplies 275 volts, each side of center tap at 90 ma with a 5-volt winding at 3 amperes, and a 6.3-volt center-tapped winding at 2.5 amperes. Provided that the physical size of the transformer is suited to our needs, this transformer will safely supply the voltages and currents needed.

Choke-Input Filter Power Supply. Now let's see what difference the use of a choke-input filter has on our choice of power transformer. Look at the *Operation Characteristics* graph (reproduced in Fig. 20-19). This graph is a little more difficult to read than the one used for the capacitor-input filter. This type is explained under the 6AX5-GT listing in your tube manual. However, for our needs, it is no more difficult to use than the other one was. From the 75.5-ma point on the horizontal axis, we erect a vertical line. From the 278-volt point on the vertical axis, we draw a horizontal line to meet the line we just drew. They meet about one fifth of the way between the 350-volt and 400-volt rms-per-plate curves, which means that the voltage per plate should be about 360 volts rms.

Again we look at the transformer listing in the catalog (Fig. 20-20) and find a transformer rated at 360 volts per plate that delivers 100 ma. This transformer will safely supply the voltages and currents that we need.

Half-Wave Rectifier Power Supplies. Transformer-operated power supplies that use a single half-wave rectifier may be divided into three main groups: those that use the transformer to isolate the rectifier

FULL WAVE -- SINGLE HIGH VOLTAGE SECONDARY

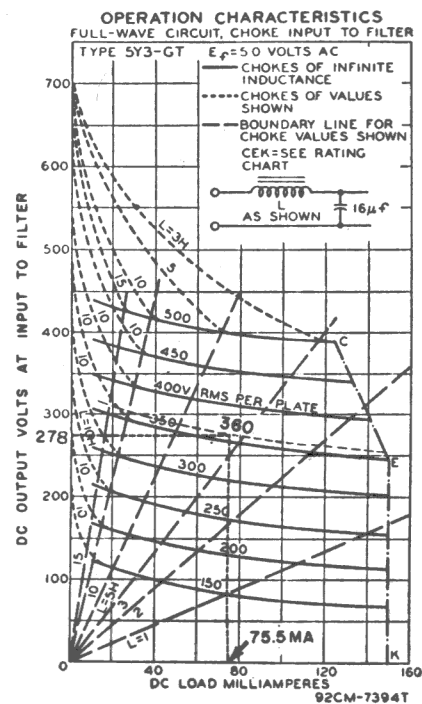
TYPE NO	LIST PRICE	PLATE SUPPLY AC VOLTS	DCMA	RECT. VOLTS	FIL. AMPS	OTHER FILS. VOLTS	AMPS	MTG. CENTERS
22R38	\$ 8.50	180-0-180	42	6.3	2.8			1 3/4 x 2 1/4
24R00	7.50	240-0-240	40	5.0	2.0	6.3 CT	2.0	2 x 2 1/2
24R00U	7.50	240-0-240	40	5.0	2.0	6.3 CT	2.0	1 5/8 x 2
22R00	8.00	250-0-250	40	5.0	2.0	6.3 CT	2.0	2 x 2 1/2
22R08	8.00	250-0-250	40	5.0	2.0	2.5 CT	4.0	2 x 2 1/2
26R31U	7.50	260-0-260	90	6.3	3.5			2 1/4 x 2
22R01	8.00	275-0-275	50	5.0	2.0	6.3 CT	2.5	2 x 2 1/2
22R09	9.00	275-0-275	50	5.0	2.0	2.5 CT	7.5	2 x 2 1/2
22R30	10.00	275-0-275	90	5.0	3.0	6.3 CT	2.5	2 x 2 1/4
22R02	10.00	300-0-300	70	5.0	2.0	6.3 CT	3.0	2 x 2 1/2
22R04	10.50	300-0-300	90	5.0	2.0	6.3 CT	3.5	2 1/4 x 2 7/8
22R05	11.50	300-0-300	120	5.0	3.0	6.3 CT	5.0	1 1/2 x 3 1/8
24R01	8.00	325-0-325	40	5.0	2.0	6.3 CT	2.0	2 x 2 1/2
24R01U	8.00	325-0-325	40	5.0	2.0	6.3 CT	2.0	1 3/4 x 2
22R10	14.00	325-0-325	85	5.0	2.0	2.5 CT	9.0	2 1/2 x 3 1/8
						2.5 CT	3.5	

Fig. 20-18

from the power line, those that use the transformer to step up the line voltage to some higher value under 500 volts, and those that step up the line voltage to a thousand volts or more. This third group, the high-voltage power supply, is discussed in the next lesson.

The type that uses the transformer to isolate the rectifier from the power line was discussed earlier in this lesson. Such transformers are listed as *isolation transformers* or, in some cases, as *half-wave rectifier transformers*. They are marked as having either a 1:1 turns ratio or a plate winding of 117 volts. Some power transformers are made for use with a half-wave selenium rectifier. Such transformers have a low-voltage secondary to supply heater volts and a plate secondary that steps up the line voltage slightly. Such a transformer has been supplied to you. You will use it in the power-supply for your signal generator. With such a transformer, your signal-generator tubes will receive heater voltage and a plate supply voltage that will enable them to work more efficiently than they would on the power line voltage. In addition, the transformer isolates the signal generator from the power line so that it may be safely used in testing other equipment. The selection of

the other power-supply parts was already discussed.



FULL-WAVE RECTIFIER		
Maximum Ratings:		
PEAK INVERSE PLATE VOLTAGE.....	1400 max	volts
PEAK PLATE CURRENT PER PLATE.....	400 max	ma
HOT-SWITCHING TRANSIENT PLATE CURRENT		
For duration of 0.2 second maximum.....	2.2 max	amperes
AC PLATE SUPPLY VOLTAGE PER PLATE (RMS).....	See Rating Chart	
DC OUTPUT CURRENT PER PLATE (RMS).....	See Rating Chart	

Fig. 20-21

filtering. However, when a half-wave transformer is needed, you'll find it listed under a catalog heading such as *Power Transformers for Half-Wave Rectifiers*. Because the high-voltage secondary of such a transformer is a single, untapped winding, the plate voltage is shown as a single voltage such as: 300, instead of 300-0-300 as in a full-wave transformer. The other parts are selected in the same way as for a full-wave power supply.

Other Electron-Tube Rectifier Ratings.

Look at the *Maximum Ratings* reproduced from the tube manual (Fig. 20-21). In the first line, it says that the *peak inverse plate voltage* of the 5Y3-GT is 1,400 volts. The peak inverse plate voltage is the maximum amount of voltage that the tube can safely withstand between its cathode and the plate when it is not conducting. In a full-wave rectifier, such as the 5Y3-GT, where one plate is always conducting, it is between the cathode and the non-conducting plate. In Fig. 20-22, a power-supply circuit is shown. The high-voltage secondary is rated at 900 volts rms (450 volts each side of the center tap). When P_2 is conducting, this makes the non-conducting plate, P_1 , negative with respect to ground by 450 volts rms, the peak value of which is 635 volts. So when the conducting plate, P_2 , is at its positive maximum, P_1 is negative with respect to ground by 635 volts. This value added to the voltage between cathode and ground is the peak inverse voltage. With a

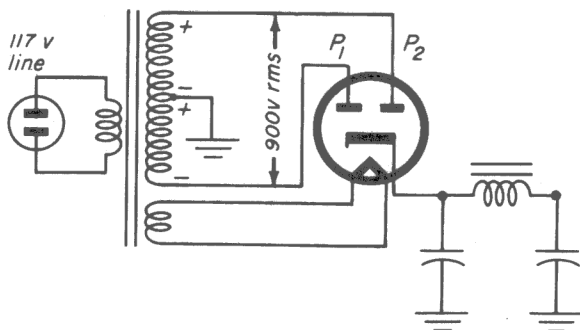


Fig. 20-22

normal load, the voltage between cathode and ground is 500 volts d.c. This would make the peak inverse voltage equal $635 + 500$, or 1,135 volts. As long as it does not exceed 1,400 volts, the 5Y3-GT can safely handle it. If it were to exceed 1,400 volts, the electrical pressure might be so great as to cause the current to arc over between the cathode and plate P_1 .

The next rating, the peak plate current, is the maximum current that the cathode can safely emit at any point in the a-c cycle — the maximum instantaneous plate current that the rectifier can safely handle. In the case of the 5Y3-GT, the peak plate current is 400 ma.

The *Hot-Switching Transient Plate Current* is the maximum value of current that the tube can safely handle when the cathode is hot and voltage is applied to the plate in pulses that last no more than 0.2 second. In other words, it is the maximum current that the tube can pass when it is conducting only in short spurts.

Power Supply Filtering. As we have already said, power-supply filtering for radio and television receivers is mostly of the brute-force type. A good rule of thumb to use in selecting filter capacitors is that the impedance of the choke should be 10 or more times the impedance of the capacitor at the lowest frequency to be amplified. For example, if the receiver passes audio frequencies as low as 30 cps, then the filter must stop all power-line and power-supply ripple voltage of 30 cps or higher. Therefore, the impedance of the choke should be 10 or more times the impedance of each filter capacitor at 30 cps. Also, as a rough rule, the resistance in an RC filter should be at least five times the reactance of the filter capacitors at the ripple frequency.

In practical filtering, start with values suggested in the tube manual. Then, if more

filtering is required, add capacity to the output capacitor or add other filter sections until the ripple voltage is cut down to the desired value. We measure the effectiveness of the filter by calculating the *ripple factor*. The ripple factor is the ratio found by dividing the rms value of the ripple voltage by the value of the output d.c.

$$K_r = \frac{E_r}{E_{dc}}$$

where:

K_r = ripple factor

E_r = rms value of ripple voltage

E_{dc} = value of output d.c.

For example, if $E_r = 0.75$ volt and $E_{dc} = 300$ volts, the ripple factor is found in this way:

$$\begin{aligned} K_r &= \frac{E_r}{E_{dc}} \\ &= \frac{0.75}{300} \\ &= 0.0025 \end{aligned}$$

More often the ripple is expressed as a percentage of the output voltage:

$$\text{Percent } E_r = \frac{E_r}{E_{dc}} \times 100$$

So, the example above would be expressed in this way:

$$\text{Percent } E_r = \frac{E_r}{E_{dc}} \times 100$$

$$= \frac{0.75}{300} \times 100$$

$$= 0.25 \text{ percent}$$

Allowable values of ripple depend upon the type and purpose of the equipment to be supplied with power. Certain amplifiers, which you'll study in later lessons, may be supplied with power that has as high as 5-percent ripple. On the other hand, microphone circuits are supplied with power that have ripple percentages as low as 0.001 percent. Radio receivers are usually powered by supplies with a ripple voltage of 0.25 percent or less; while filtering for video circuits in television receivers should be 0.2 percent or less.

Voltage Rating of Capacitors. In selecting filter capacitors, particularly input filter capacitors, care should be taken to select capacitors that can withstand the peak value of the a-c input voltage to the rectifier. When the load is very light, the d.c. supplied to the input capacitor by the rectifier is only slightly lower than this value.

In the next lesson, we will discuss special power supplies and power supply circuits. You will learn about voltage doublers, triplers, and quadruplers, vibrator power supplies, voltage converters, voltage regulators, and other useful facts about power supplies.